

## **General Disclaimer**

### **One or more of the Following Statements may affect this Document**

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.
- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.
- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.
- This document is paginated as submitted by the original source.
- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

# NATURAL RESOURCES PROGRAM

SPACE APPLICATIONS  
PROGRAMS

TECHNICAL LETTER NASA-57

N70-38889

(ACCESSION NUMBER)

FACILITY FORM

16

(PAGES)

(NASA CR OR TMX OR AD NUMBER)

1

(CODE)

(CATEGORY)

U.S. Geological Survey  
Department of the Interior



UNITED STATES  
DEPARTMENT OF THE INTERIOR  
GEOLOGICAL SURVEY  
WASHINGTON, D.C. 20242

Technical Letter  
NASA - 57  
August 1966

Dr. Peter C. Badgley  
Chief, Natural Resources Program  
Office of Space Science and Applications  
Code SAR, NASA Headquarters  
Washington, D. C. 20546

Dear Peter:

Transmitted herewith are 2 copies of:

TECHNICAL LETTER NASA-57  
LIQUID NITROGEN ELACKBODY FOR  
SPECTRAL EMITTANCE STUDIES\*

by

D.L. Daniels and A.E. Stoddard

Sincerely yours,

William A. Fischer  
Research Coordinator  
Earth Orbiter Program

\*Work performed under NASA Contract No. R-146-09-020-006



UNITED STATES  
DEPARTMENT OF THE INTERIOR  
GEOLOGICAL SURVEY

TECHNICAL LETTER NASA-57

LIQUID NITROGEN BLACKBODY FOR  
SPECTRAL EMITTANCE STUDIES

by

D.L. Daniels and A.E. Stoddard

July 1966

These data are preliminary and should  
not be quoted without permission

Prepared by the Geological Survey  
for the National Aeronautics and  
Space Administration (NASA)

## Liquid nitrogen blackbody for

## Spectral emittance studies

by

D.L. Daniels and A.E. Stoddard

### INTRODUCTION

This letter reports preliminary considerations and experiments concerning use of a blackbody maintained at liquid nitrogen temperature in the study of spectral emittance of rocks in situ or in the laboratory. Providing that the sample studied and a reference blackbody assume the same arbitrary temperature, the method provides a rather simple, absolute determination of spectral emissivity utilizing the Block interferometer type spectrometer.

### THEORY

Radiation incident upon the bolometer detector of the Block Interferometer consists of two parts, each varying at an audio frequency  $\omega$  proportional to the wavenumber  $\nu$  of the radiation. The first part arises from radiation entering the instrument from outside, and is given by:

$$I_{\nu} = H_{\nu} I_{\nu}^i (1 + \cos \omega t)$$

$I_{\nu}^i$  is the intensity of radiation incident upon the instrument at the wavenumber  $\nu$  and  $I_{\nu}$  is the transmitted intensity incident upon the bolometer.  $H_{\nu}$  is the so-called "modulation efficiency," a proportionality constant. The second part arises from radiation from the bolometer detector which is "reflected" back onto itself by the interferometer. At the same wavenumber the intensity of this radiation is shifted in phase by  $180^\circ$  with respect to the "transmitted" radiation, and is given by:

$$I_{\nu} = H_{\nu} I_{\nu}^d (1 - \cos \omega t)$$

The bolometer responds to the sum,

$$H_{\nu} (I_{\nu}^i + I_{\nu}^d) + H_{\nu} (I_{\nu}^i - I_{\nu}^d) \cos \omega t$$

of these incident intensities.

The output of the Block Interferometer is proportional to the amplitude of the second, or audio frequency term in the radiation intensity incident upon the bolometer. Denoting this output by  $A_\nu$ , the amplitude of the chart recorder trace at wavenumber  $\nu$ , then

$$A_\nu = R_\nu |I_\nu^i - I_\nu^d|$$

Where  $R_\nu$ , the "responsivity," is a proportionality constant consisting of  $H_\nu$  and the gain settings of the interferometer.

Three measurements of  $A_\nu$  are required to determine emissivity. First, the incident intensity with the instrument directed at the rock surface is given by:

$$I_\nu^r + (1-\epsilon_\nu) I_\nu^s$$

where  $I_\nu^r$  is the thermal emission of the rock,  $\epsilon_\nu$  its emissivity and  $I_\nu^s$  the radiation from the sky reflected by the rock into the instrument. Normally  $I_\nu^s \sim 0.1 I_\nu^r$  in the 8-14 $\mu$  band and  $\epsilon_\nu \sim 0.8$  so that the second term is  $\sim 0.02 I_\nu^r$  and may be neglected. Under these conditions this measurement yields

$$A_\nu^r = R_\nu |I_\nu^r - I_\nu^d|$$

Second, the incident intensity with the instrument directed at a reference blackbody at the temperature of the rock is  $I_\nu^{bb}$ , giving a recorder output of

$$A_\nu^{bb} = R_\nu |I_\nu^{bb} - I_\nu^d|$$

Third, the incident intensity with the instrument directed at a cold blackbody at liquid nitrogen temperature is essentially zero. The recorder output amplitude with this blackbody filling the field of view is thus,

$$A_\nu^n = R_\nu I_\nu^d$$



Generally the detector will be at a common temperature with the reference blackbody and rock surface. Then  $I_v^{bb} \geq I_v^d \geq I_v^r$ , so that:

$$\begin{aligned} A_v^r &= R_v (I_v^d - I_v^r) \\ A_v^{bb} &= R_v (I_v^{bb} - I_v^d) \\ A_v^n &= R_v I_v^d \end{aligned}$$

Eliminating  $I_v^d$  and  $R_v$ , and rearranging,

$$\frac{I_v^r}{I_v^{bb}} \equiv \epsilon_v = \frac{A_v^n - A_v^r}{A_v^n + A_v^{bb}}$$

It is observed, under these conditions, that  $A_v^{bb}$  is very nearly zero due to the near cancellation of  $I_v^{bb}$  and  $I_v^d$ . To this approximation only two measurements are required and:

$$\epsilon_v \approx 1 - \frac{A_v^r}{A_v^n}$$

#### The liquid nitrogen blackbody

The liquid nitrogen temperature blackbody was constructed by spraying 3M Velvet Coating black paint over the interior of a 2 3/4" I.D. by 9 1/4" overall height, one pint pyrex dewar. This paint is quite resistant to thermal shock, whereas Parson's Black flakes at low temperature. Other paints may be found which are superior. The dewar was filled with liquid nitrogen to within a half inch of the top and viewed directly by the interferometer at a distance of approximately two inches. In this configuration a thin, broken water cloud wavers over the liquid surface. This cloud could be eliminated by proper design, but it was observed not to reflect infrared from a hot soldering iron into the interferometer.

The recorder amplitude when the instrument views this blackbody should depend only upon the detector temperature, and should increase as the detector temperature is increased. Runs with the detector at 29, 34, 40, 45 and 50°C showed this effect. Figure 1 show the ratio of the recorder amplitudes with the detector at elevated temperatures to the amplitude at 29°C for selected wavelengths. The increase is greater than the corresponding

ratios of the intensity of detector emission at these temperatures as calculated from the Planck formula. It had been anticipated that amplitude ratios smaller than corresponding emission ratios would measure the reflection of room radiation by the cold blackbody. The reverse behavior is apparently due to an increase in responsivity of the detector with temperature. The necessary increase in responsivity is also shown in figure 1 and is, as yet, unexplained.

### Results

Two polished samples, a microcline feldspar single crystal (260) and quartz monzonite (316), and a Parson's Black coated aluminum block were placed in the shade on the roof of the building. The sample and detector were so oriented that any reflected radiation reaching the detector was from the clear sky. The interferometer output for these sources and the cold blackbody are shown in figure 2. The data was reduced according to the expression

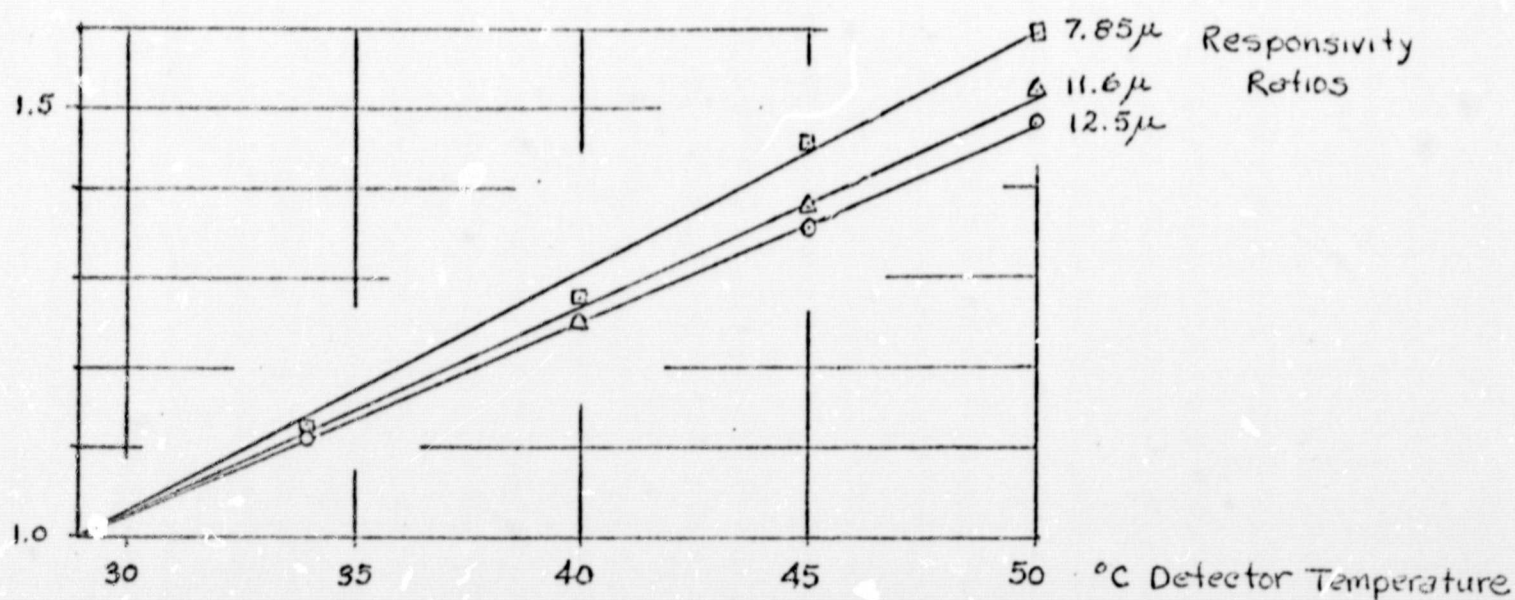
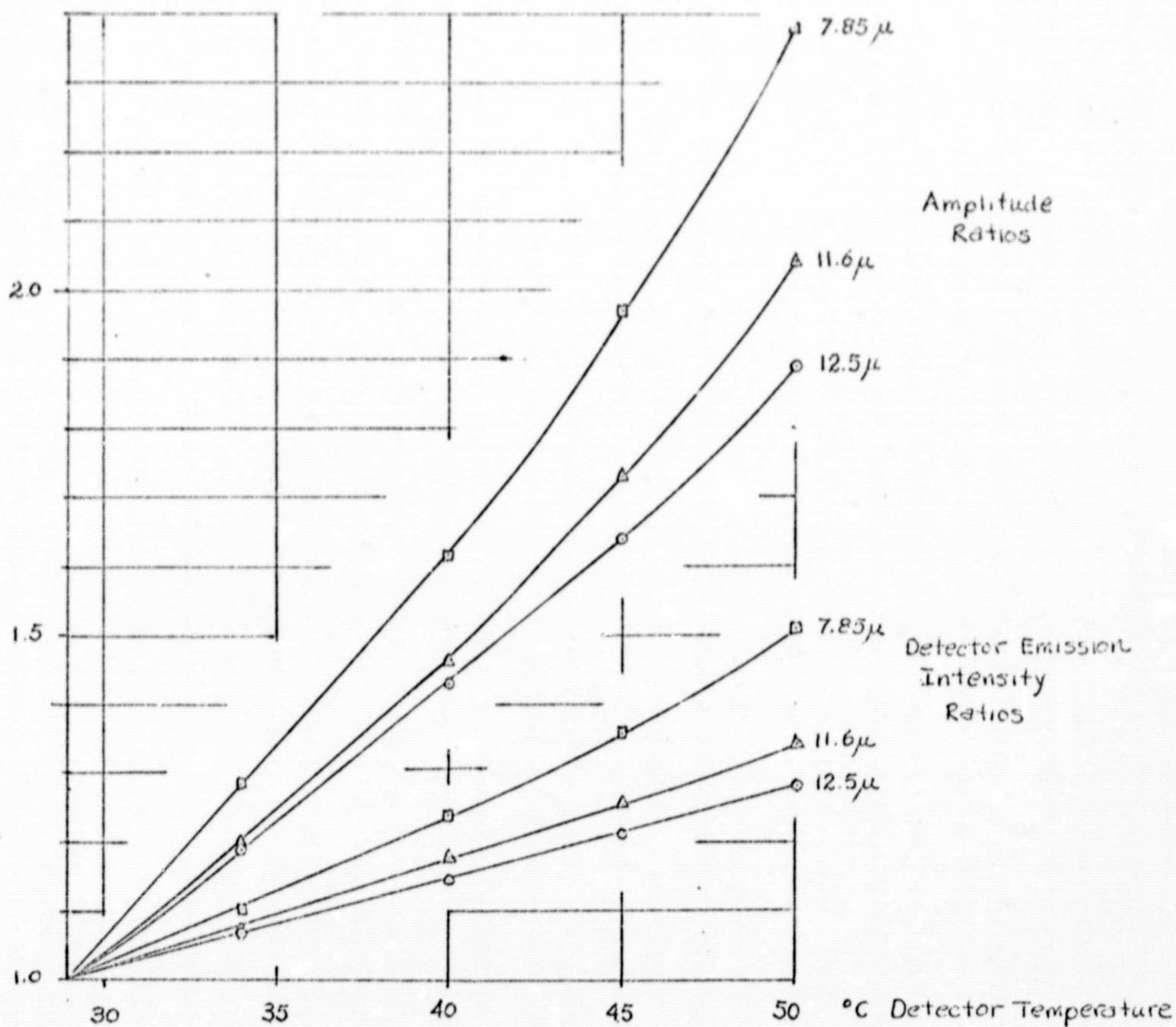
$$\epsilon_v \approx 1 - \frac{A_r}{A_v}$$

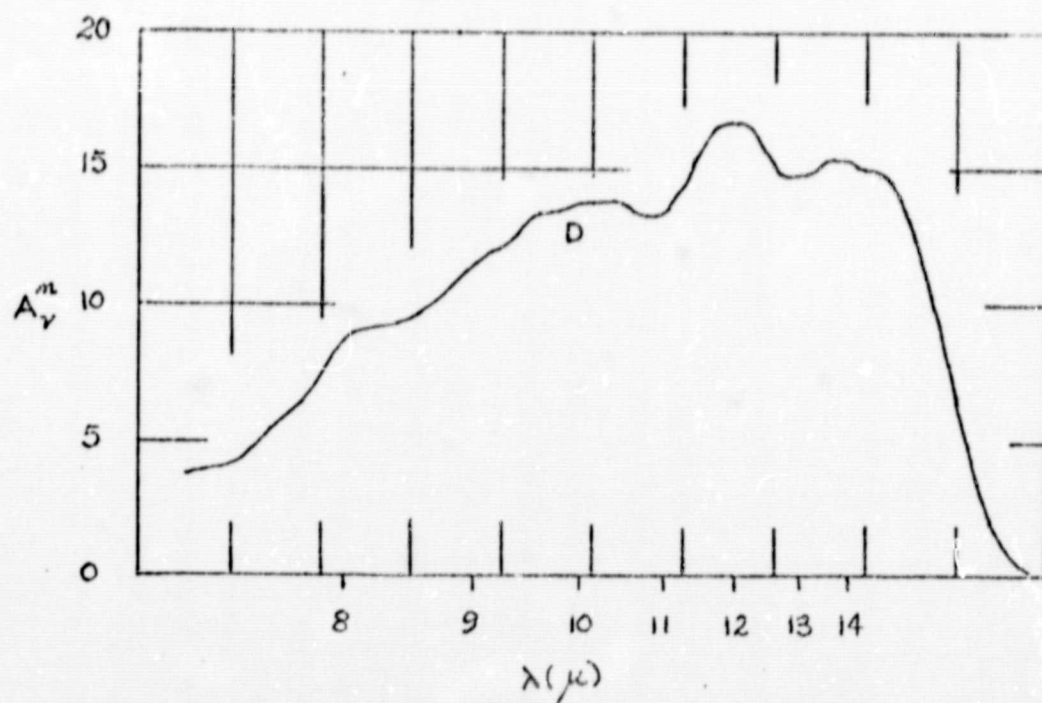
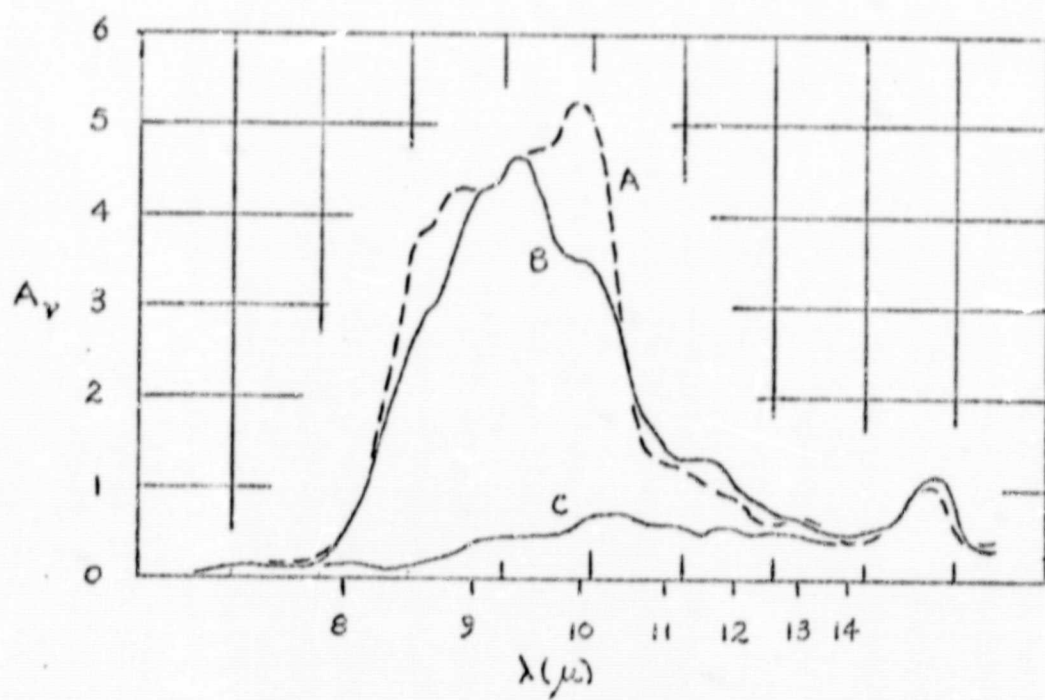
with the results shown in figure 3. The emissivity curves for these samples compare favorably with those determined by the laboratory procedure given by Daniels (1966).

### Reference

Daniels, D.L., 1966, Infrared spectral emittance of rocks from the Pisgah Crater and Mono Craters areas, California: U.S. Geological Survey Technical Letter NASA-13. (in preparation)

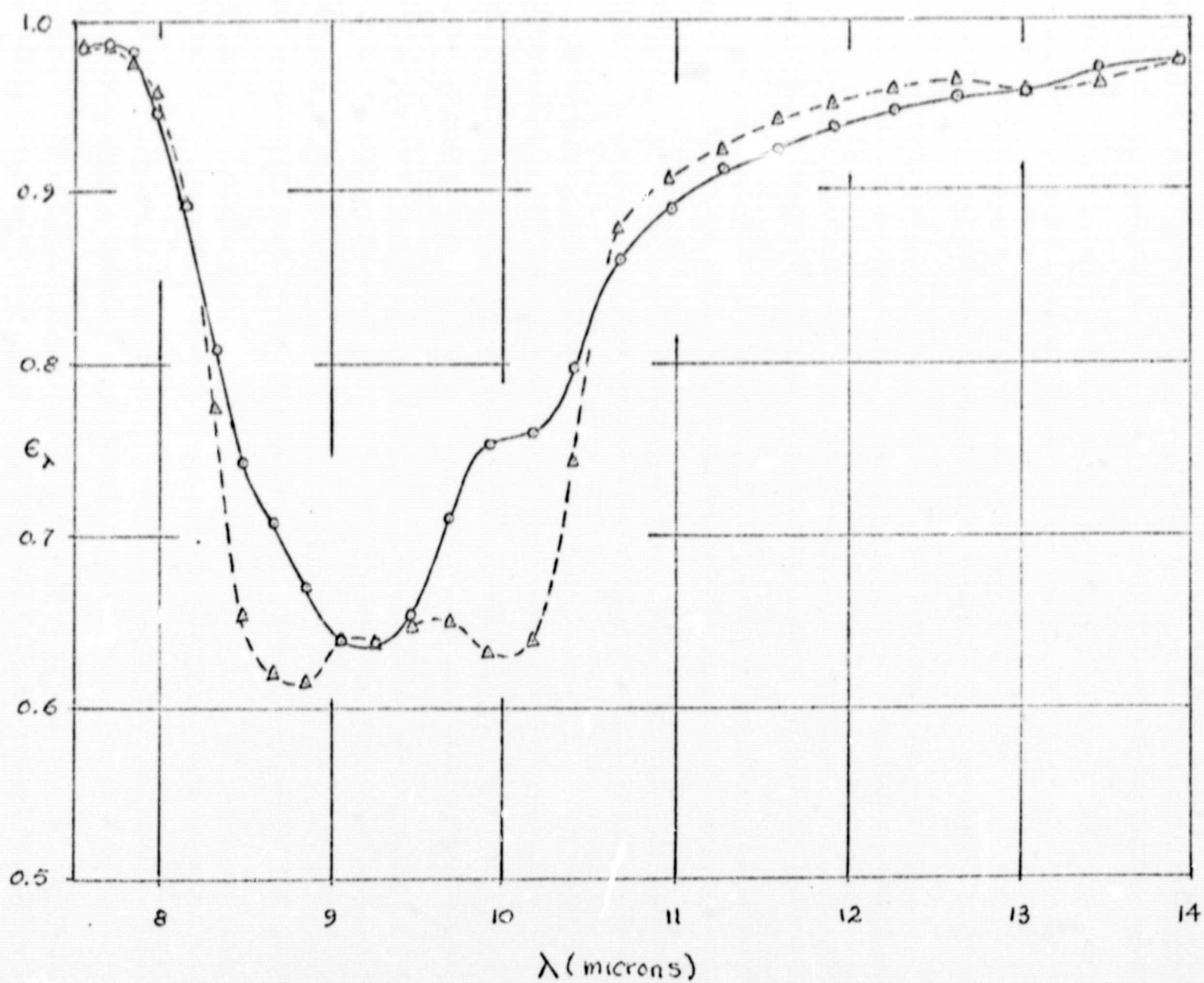






- |                    |                                    |
|--------------------|------------------------------------|
| A - sample no. 260 | C - reference black body           |
| B - sample no. 316 | D - cold black body (scale change) |

Figure 2.



— 316  
- - - 260

Figure 3.